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The Effect of Consuming Salt and Vinegar-Washed Vegetables on Serum Electrolyte Levels in Male Wistar Rats

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Abstract:

Background: Salt and vinegar are commonly used to wash vegetables to remove contaminants and improve food safety. However, their impact on the nutritional profile of vegetables, particularly the electrolyte content, and the subsequent physiological effects on consumers, remains underexplored.

Objective: This study aimed to investigate the effect of consuming salt and vinegar-washed vegetables on serum electrolyte (sodium, potassium, chloride, phosphorus) levels in a Male Wistar rat model.

Methods: Twenty male Wistar rats were divided into five groups (n=4/group). Group I (control) received a normal diet with vegetables washed in plain water. Groups II and III received vegetables washed in 0.75g/250mL and 1.50g/250mL salt solutions, respectively. Groups IV and V received vegetables washed in vinegar solutions at 1:4 and 2:4 dilutions, respectively. The intervention lasted 28 days. Serum electrolytes were analyzed using ion-selective electrode (sodium, potassium, chloride) and ammonium molybdate (phosphate) methods.

Results: The consumption of salt-washed vegetables led to a significant ($p \leq 0.05$) increase in serum sodium, chloride, and potassium levels compared to the control group. Serum sodium and chloride levels were not significantly ($p \geq 0.05$) altered in the Vinegar-washed vegetables; however, a significant ($p \leq 0.05$) increase in potassium and phosphate levels was observed at the lower vinegar concentration (1:4), which decreased at the higher concentration (2:4).

Conclusion: Washing vegetables with salt significantly increases the bioavailability of electrolytes, potentially disrupting homeostasis. In comparison, Vinegar washing is a more favorable method, with minimal impact on sodium and chloride levels and a nonlinear effect on potassium and phosphate. These findings suggest that dietary advice should consider vegetable preparation methods.

Keywords: electrolyte balance, sodium, potassium, food processing, acetic acid, dietary sodium, animal model.

Introduction

Consuming vegetables is a cornerstone of a healthy diet and provides vital vitamins, minerals, and fibre (Aune et al., 2017). However, vegetables may contain dirt, pesticides, and pathogenic microorganisms, which makes proper washing an important food safety step (Centers for Disease Control and Prevention [CDC], 2020). Using vinegar or salt solutions for this purpose is a common household practice. Vegetable cell walls are thought to be softened by salt (sodium chloride), which releases debris and prevents microbial growth (Lee, 2018). Acetic acid, or vinegar, uses its antimicrobial and antifungal qualities to get rid of pollutants like E. coli as well as Salmonella (Kim, 2017).

Although these agents' antimicrobial effectiveness is frequently discussed, little is known about how they affect vegetables' nutritional makeup, particularly their electrolyte content. Electrolytes like phosphate (PO_4^{3-}), sodium (Na^+), potassium (K^+), and chloride (Cl^-) are crucial for maintaining physiological homeostasis, including nerve conduction, muscle contraction, fluid balance, and cellular function (Shrimanker & Bhattarai, 2024). Disruptions in electrolyte balance are linked to hypertension, cardiovascular disease, and metabolic disorders (Nikolaienko et al., 2020).

One of the main sources of electrolytes is diet. Food processing, including washing, can change how these minerals leach or are retained. While the acidity of vinegar may affect the bioavailability of minerals like potassium and phosphate, salt washing may directly add sodium and chloride ions to vegetables. Although these techniques are widely used, there isn't a comparative study of how they affect the electrolyte profile of vegetables and the ensuing physiological reaction.

Therefore, the purpose of this study was to assess how eating salt and vinegar-washed vegetables affected the male Wistar rats' serum electrolyte levels. The results will influence public health recommendations and offer insightful information about the nutritional effects of typical food preparation methods.

Materials and Methods

2.1 Ethical Approval

Ethical approval for this study was obtained from the Usmanu Danfodiyo University Health Research Ethics Committee (UHREC). All procedures involving animals were conducted in strict accordance with approved guidelines.

2.2 Study Design and Animals

Twenty (20) healthy adult male Wistar rats (weighing 150–200 g) were acquired from the animal house of the Faculty of Pharmaceutical Sciences, Usmanu Danfodiyo University, Sokoto. The rats were acclimatized for two weeks under standard laboratory conditions (12h light/dark cycle, 25 ± 2°C, 40-60% humidity) with free access to standard pellet feed and water.

After acclimatization, the rats were randomly divided into five groups (n=4 per group):

- Group I (Control): Fed a normal diet + vegetables washed in 250 mL plain water.
- Group II (Low Salt): Fed a normal diet + vegetables washed in 0.75g salt/250mL water.
- Group III (High Salt): Fed a normal diet + vegetables washed in 1.50g salt/250mL water.
- Group IV (Low Vinegar): Fed a normal diet + vegetables washed in vinegar at a 1:4 dilution (62.5 mL vinegar + 187.5 mL water).
- Group V (High Vinegar): Fed a normal diet + vegetables washed in vinegar at a 2:4 dilution (125 mL vinegar + 125 mL water).

The intervention lasted for 28 days. Fresh solutions were prepared daily, and a mixed variety of commonly consumed vegetables (e.g., spinach, tomatoes, carrots) was used.

2.3 Sample Collection and Biochemical Analysis

Rats were fasted overnight and given chloroform inhalation to induce anesthesia following the 28-day intervention. Lithium heparin tubes were used to collect blood samples through cardiac puncture. Plasma was extracted from the blood by centrifuging it at 4000 rpm for five minutes. It was then kept at -20°C until analysis.

An ion-selective electrode (ISE) analyzer was used to measure serum levels of sodium, potassium, and chloride (Bishop, 2013). The ammonium molybdate method, which involves phosphate reacting to form a phosphomolybdate complex reduced to a blue compound by ascorbic acid and measured spectrophotometrically at 640 nm, was used to estimate serum inorganic phosphate.

Statistical Analysis

Data are presented as mean ± Standard Error of the Mean (SEM). Statistical analysis was performed using SPSS version 26.0. Differences between groups were analyzed using a one-way analysis of variance (ANOVA), followed by appropriate post-hoc tests. A p-value ≤ 0.05 was considered statistically significant.

Result

The effects of consuming salt and vinegar-washed vegetables on serum electrolyte levels are presented in Tables 1 and 2.

Effect of Salt-Washed Vegetables

Serum electrolyte profiles were significantly changed when vegetables washed in salt solutions were consumed (Table 1). Serum sodium and chloride levels were significantly higher ($p \leq 0.05$) in the low-salt (Group II) and high-salt (Group III) groups than in the control group (Group I). Additionally, both salt-treated groups had significantly higher potassium levels ($p \leq 0.05$). The low-salt group showed a notable rise in phosphate, but the high-salt group did not experience this effect.

Table 1. Effect of Salt-Washed Vegetables on Serum Electrolyte Levels

Group	Treatment	Sodium (mmol/L)	Potassium (mmol/L)	Chloride (mmol/L)	Phosphate (mmol/L)
I	Control (Water)	135.50 ± 1.71a	4.78 ± 0.23a	94.25 ± 1.11a	1.07 ± 0.02a
II	Low Salt (0.75g/250mL)	143.75 ± 0.85b	6.28 ± 0.14b	99.00 ± 0.58b	1.47 ± 0.02b
III	High Salt (1.50g/250mL)	146.75 ± 0.48b	6.33 ± 0.68b	99.00 ± 1.08b	1.17 ± 0.09a

Note: Values are Mean ± SEM (n=4). Means in the same column with different superscript letters (a, b) are significantly different (p ≤ 0.05).

Effect of Vinegar-Washed Vegetables

Washing vegetables with vinegar had a more moderate effect than salt (Table 2). Serum sodium and chloride levels did not differ significantly ($p \geq 0.05$) between the vinegar-treated groups (IV and V) and the control group. Potassium did, however, significantly increase ($p \leq 0.05$) in the low-vinegar group (IV) and then significantly decrease ($p \leq 0.05$) in the high-vinegar group (V), although it was still higher than control levels. Phosphate showed a similar pattern, increasing significantly at low concentrations and returning to control levels at high concentrations.

Table 2. Effect of Vinegar-Washed Vegetables on Serum Electrolyte Levels

Group	Treatment	Sodium (mmol/L)	Potassium (mmol/L)	Chloride (mmol/L)	Phosphate (mmol/L)
I	Control (Water)	135.50 ± 1.71a	4.78 ± 0.23a	94.25 ± 1.11a	1.07 ± 0.02a
IV	Low Vinegar (1:4)	135.25 ± 0.75a	9.35 ± 1.45b	96.00 ± 2.97a	1.31 ± 0.10b
V	High Vinegar (2:4)	134.75 ± 1.18a	7.58 ± 0.60c	96.50 ± 1.23a	1.18 ± 0.02a

Note: Values are Mean ± SEM (n=4). Means in the same column with different superscript letters (a, b, c) are significantly different (p ≤ 0.05).

Discussion:

This study shows that, as modeled in Wistar rats, the technique used to wash vegetables can have a substantial impact on their electrolyte content, which in turn affects the serum electrolyte balance in consumers.

It was expected that rats eating salt-washed vegetables would have significantly higher serum sodium and chloride levels. Since sodium chloride is highly soluble, the washing process probably causes the vegetables to absorb and/or retain Na^+ and Cl^- ions on their surface before being consumed (Li et al. (2016)). Given the established connection between high sodium consumption and hypertension, this finding is physiologically significant (Nikolaienko et al., 2020). Given that high sodium consumption frequently encourages kaliuresis (potassium excretion), the rise in potassium levels was more unexpected (Šilhavý et al. (2022). The observed increase could be the result of a complex physiological reaction to the salt load or a direct additive effect from the vegetables.

The vinegar-washed groups' results paint a more complex picture. One important benefit of vinegar over salt as a washing agent, especially for people on sodium-restricted diets, is the lack of a discernible impact on sodium and chloride levels. It's interesting to note the substantial but nonlinear impact on phosphate and potassium. The first increase at the lower vinegar concentration (1:4) might be caused by acetic acid breaking down plant cell walls, which makes it easier for minerals like phosphate and potassium to leach into the solution and be adsorbed onto the vegetable surface. The formation of complexes that lower the bioavailability of these minerals or a more noticeable denaturing effect on vegetable tissues could be the cause of the decrease in this effect at the higher concentration (2:4). This implies that the amount of vinegar used has a significant influence on its nutritional value.

From a public health perspective, these findings suggest that vinegar may be a preferable alternative to salt for washing vegetables, especially for populations aiming to reduce their sodium intake. However, more research is necessary because vinegar may change the bioavailability of advantageous minerals like potassium, depending on its concentration.

Conclusion and Recommendations

According to the study's findings, washing vegetables with salt solutions greatly raises the amount of sodium, chloride, and potassium in the diet, which may upset electrolyte homeostasis. On the other hand, washing with vinegar solutions, especially at moderate concentrations, may increase the bioavailability of potassium while having little effect on sodium and chloride.

Based on these findings, we recommend:

1. **Public Awareness:** Health education programs should advise against the use of salt for washing vegetables, emphasizing its contribution to total dietary sodium intake.
2. **Use of Vinegar:** Vinegar (at a recommended dilution of 1:4) should be promoted as a safe and effective alternative for washing vegetables, with minimal risk of altering sodium balance.
3. **Further Research:** Future studies should focus on identifying the optimal vinegar concentration that maximizes antimicrobial efficacy without negatively affecting the mineral profile of vegetables. Research in human subjects is also needed to confirm these findings.

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